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Lost in the problem: The role of boundary organizations in the social status of climate change knowledge

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Abstract

A plethora of institutional forms has emerged whose remit is to link climate change science to policy-making. These can be understood as boundary organisations where science and politics meet and intertwine. This article examines the role of boundary organisations in the production and social status of climate change knowledge. A multi-level conceptual model is outlined which demonstrates how context is crucial to understanding the operation and impact of boundary organisations. The framework is applied to analyse climate governance boundary arrangements at the international level and a number of national contexts. In the framing years of the global climate change issue, IPPC and other (inter)national boundary organisations were set up for addressing a (moderately) structured problem, instead of geared to an as yet full-blown wicked problem. IPPC was in fact designed as 'certification machine' and 'scientific trigger' to depoliticize a multilateral international agreement and its supposedly smooth implementation. Boundary arrangements at national levels showed cognitive and institutional isomorphic responses; the highly instrumental nature of boundary arrangements, organisations and projects stands out. However, it is becoming increasingly apparent that 'one size fits all' policy instruments such as Kyoto may not be the best mechanism for dealing with climate change. We therefore end with a call for boundary work in climate change governance to provide pluralized strategic advice, conceptual clarification, and critical deconstruction of issues of uncertainty and normativity. In order to open up debate again it should be more problem- than solution-orientation and influence different agendas in different parts of the world.

Like many environmental problems, climate change has become visible and comprehensible only as a result of increasing scientific knowledge. Compiled by the Intergovernmental Panel on Climate Change (IPCC), climate science has been at the heart of attempts to build a comprehensive global policy regime centred around the UN Framework Convention on Climate Change (UNFCCCC).[1] Until recently, the IPCC commanded such public trust that it was awarded the Nobel Peace prize in 2007. However, in 2009 this trust was shaken primarily as a result of 'climategate' and the discovery of errors in the 4th IPCC assessment report.[2, 3] This fuelled climate scepticism, as well as (arguably) contributing to deadlock in the negotiations of the 2009 Conference of Parties (COP15) in Copenhagen. In the debate on the role of IPCC after 'climategate', the InterAcademy Council paid a lot of attention to credibility issues by sharpening up the review procedure. Less attention was given to legitimacy and salience issues, or more generally to the role assigned to IPCC in the international and national climate policy regimes, while these issues are at least as significant for the social status of climate change knowledge. From these perspectives, 'climategate' was waiting to happen, as anticipated by Demeritt in 2001.[4] This review shows how the boundary work perspective is appropriate to aid reflection on the interaction between climate science, policy and politics. Yet, there are many 'blind spots' since the boundary work lens has not been applied frequently enough in the study of (global or national) climate change science-policy interactions to yield an exhaustive view of the state of affairs.

In this review article we show how the characteristics of science-policy interactions in the global climate policy regime help to understand why UNFCCCC implementation is stalling. We analyse science-policy interactions using Hoppe's (2010) multi-level framework[5, 6] that depicts how boundary work between science and politics takes place in contexts of political-cultural spheres, policy issue politics, boundary arrangements and boundary organisations, and finally in boundary projects. From the perspective of productive boundary work, two mistakes were made in global climate change governance. First, from the start it followed a linear approach to science-policy interaction.[7, 8] IPCC was set up as a scientific endeavour that assumed climate change was a technical issue, ignoring fundamental disagreements on goals and deep uncertainty on facts and means. In other words, IPCC was set up as a specialist advisory body to help deal with what was framed as a structured problem, when in fact climate change was and still is a paradigmatically 'wicked' or unstructured problem.[9] When such circumstances prevail, boundary work should be as much about opening up as about closing down policy debates.[10] By focusing on a single policy framework, the UNFCCCC-Kyoto protocol, the political space for debate was effectively closed down. In 'climategate' and the events in its wake legitimate boundary management of science-policy interaction exposed itself to serious allegations of management-by-hypocrisy.[11] Hence, Sarewitz[12] plausibly argues that support for global climate policy has become indistinguishable from support for climate science, and political opposition to UNFCCCC is expressed as distrust of the science. This analysis provides an important alternative to the frequently heard argument that what is blocking progress on the climate issue is a lack of scientific certainty[13] or the predominance of climate scepticism.[14]

Second, climate change was from the start framed as a global issue for which global solutions had to be found.[15] However, although the IPCC claims to produce universal, 'policy relevant but policy neutral' science, this science is not universally accepted as valid and authoritative. As global climate policy-making matured, national boundary arrangements and issue politics became involved that were differentially impacted by 'universal' climate change science. In addition, the geographic bias towards participation by experts from developed countries in IPCC assessments means that the

issues raised by the global South are marginalised or ignored.[16, 17] Below, we identify key issues that influence the effectiveness of boundary work. We then describe boundary arrangements at the international level and responses in selected countries. We conclude with a discussion of the direction for learning lessons for improved boundary work.

BOUNDARY ORGANISATIONS: A MULTILEVEL HEURISTIC FRAMEWORK

The relationship between science and politics is often conceptualized as a linear process of knowledge transfer, dissemination, research use or impact.[18-20] Policymakers and politicians like to suggest that they are 'on top' and call on the services of scientists and experts who supposedly are just 'on tap'. Scientists see their role as neutral, objective and independent, speaking 'truth to power'. However, both 'sacred' narratives neglect the more 'profane' truth of the two-way, interdependent character of knowledge production and communication between experts and policymakers. To draw together usable insights from this older work and more recent research perspectives,[21-25] this review uses a multilevel heuristic for understanding science-policy interaction.[5, 6]

The production of policy advice cannot be described in terms of clear boundaries between science and politics. The zones of engagement and transgression are inevitably fluid and vague. From a macro-perspective, science-policy interactions are on-going co-productions[26] between the scientization of politics and the politicization of science (Weingart 1999). At meso- and micro-level this does not mean a complete blurring of boundaries. Given the need for participation from different institutional spheres, a division of work is required. However, such a division is not easily decided upon. Experts may be sensitive to immediate demands of policy; politicians want to be seen to use 'independent' advice. However, effective use of new scientific information mostly comes about in mutual face-to-face interaction.[27] In advisory relations, for example in the International Panel on Climate Change (IPCC), experts and policy makers work together: boundary work always happens during the production of policy advice, whether intentionally or not.

Boundary work can more formally be understood as the attempts by actors to define practices in contrast to each other through *demarcation*, as well as attempts to find productive *coordination* across these boundaries through a division of labour that is more or less stabilized because it has been accepted.[28] Demarcation and coordination are two sides of the same coin. Concern for high-quality performance makes expert advisors and policymakers mutually dependent; yet, they have to guard their separate identities and formal independence. Therefore, boundary work is full of paradoxes and dilemmas: the relationship will never be smooth and easy, it will always be contested.

Boundary work can be depicted as science-policy interactions in a multilevel system (Figure 1). From a micro-perspective, science-policy boundary work is most clearly visible in research and recommendation *projects* around particular topics. At meso-level, boundary work is carried out in *boundary arrangements*, a wide variety of hybrid organisational forms that straddle and mediate the boundary between professional-academic networks and public sector or policy organisations, of which formal *boundary organisations* are one type. At the next level, such boundary arrangements usually cluster around the typical problems in a specific issue or policy network. These *problem-and-*

network structures in turn are embedded in a *political-cultural sphere*, the characteristics of which influence science-policy interfaces on all levels. To present a comprehensive picture of the science-policy interfaces relevant to global climate change, then, means to understand multilevel science-policy interactions and the ways these levels interact. In the descriptions of global and national boundary work we focus on the meso-level of boundary arrangements for climate change. Details of other levels are addressed only where relevant.

[Insert Figure 1 here]

Boundary arrangements

Boundary arrangements typically display several ingredients.[22, 24, 29] Not all of these occur in each boundary arrangement and each may be present in stronger or weaker form:

Double participation: people from both the policy/politics and the scientific world are represented and participate in the activities of the boundary organisation or arrangement. For example, in IPPC government-appointed scientists, diplomats representing national governments, NGOs and business representatives interact in varying configurations.[30, 31]

Dual accountability: the leadership or management is simultaneously accountable to representatives of science and politics. For example, the European Environment Agency has a Management Board to deal with political issues like salience and legitimacy, and a Scientific Board to attend to issues of scientific credibility.[32] This leads to a (necessary) split between sacred or front-office narratives of boundary work for official use in external accountability relations, e.g. to members of parliament and the press, and profane or back-office 'insider' narratives in internal accountability relations, e.g. between experts of different advisory bodies and departmental policy makers.[33-35] This 'double-speak' is reflected in different scientific accounts of the science-policy interface: linear transfer being the sacred story and boundary work the profane account.

Boundary objects: the creation and maintenance of a well-chosen set of boundary objects or standardised packages[36, 37] that generate a 'world' in which both scientists and policymakers may coordinate their activities without denying or compromising their different identities and skills. Examples are indicator systems, econometric or climate models, report series, etc. In IPCC, key texts like the Statement for Policymakers and the Synthesis Reports are typical examples of boundary objects[30, 31] since they are the result of procedural and substantive intertwinement of scientific and political considerations.

Hybrid management: Miller[24] usefully postulates that "(t)o maintain … productive and dynamic relationships, boundary organisations need to be able to manage hybrids (Reference 25, p. 487). Hybrid management consists of:

(a) Hybridization: the creation and stabilization of standard methods for knowledge production in order to comply to the criteria of different expert, policy and political audiences. For example, the measurement of greenhouse gas emissions

(b) Deconstruction: the opening up of hybrids to reveal their tacit value-laden and political assumptions in order to facilitate debate and so help prevent future controversies and enhance policy effectiveness (*ibid* p. 491).

(c) Demarcation: as part of their boundary work on emissions inventories, SBSTA has designated certain activities as scientific and others as political, and allocated them to the IPCC or the Conference of Parties respectively.

(d) Meta-governance and capacity building: This is the cross-jurisdictional, cross-level and cross-scale orchestration of distributed knowledge production and policymaking. Although the activities of scientific experts and political players taking place in the two domains must appear separate, for purposes of legitimacy, they must also be coordinated.

Boundary work in projects

Micro-level *projects* reveal practices where the boundary is at its most fuzzy and sometimes even 'up for grabs', as it has to be negotiated and renegotiated in the smallest details, for example when the Statement for Policymakers and the Synthesis Reports were produced for the first time by the IPCC Working Groups. Important aspects of micro-level boundary work in projects are unwritten rules, habits and expectations for dealing with uncertainty, with conflicting knowledge, and with different knowledge types; the impact of project design on learning by participants; maintenance, building or erosion of trust; and the organisational flexibility of the project itself.

From this project level all kinds of *impacts* emanate, both to the academic/professional and the policy/political worlds. In the political/policy world, the key distinction between research as 'data' (instrumental use), 'ideas' (conceptual use) and 'ammunition' (political-strategic use) neatly summarizes most more detailed and fluid classifications.[20] The quality of boundary work itself is usually evaluated by the degree to which criteria of *credibility* (technically adequate in handling of evidence), *legitimacy* (fair, unbiased, respectful of all stakeholders) and *salience* (relevant to the decision or policy) are simultaneously achieved for multiple stakeholders.[29] Impacts of boundary work projects on academic/scientific networks in the longer term are e.g. reputation, knowledge demand steering, opportunities for knowledge dissemination, and resource security.

Policy issue politics

Boundary organisations and arrangements are part of larger policy networks. Such networks have *policy issue politics*, i.e. the particular combination of cognitive processes ('puzzling') and competitive interaction ('powering') that are characteristic for policymaking in a particular domain.[38] Policy issue politics constrains what types of boundary arrangements are effective because they structure the policy problem. In the case of solidly structured problems (strong value consensus and knowledge certainty) a central-rational rule approach to governance permits 'outsourcing' problem solving to bureaucratic or scientific/professional, closed epistemic communities.[39] In the case of unstructured or 'wicked' problems (high value dissent and lasting deep uncertainties) an agonistic governance style will come about, allowing numerous and different types of stakeholders to play a role, perhaps with flexible boundary arrangements as spaces for open deliberation and social learning. Intermediate problem types of moderately structured problems (goals or means) give rise to temporary pragmatic, professional or advocacy networks and arrangements.[38]

Political-cultural sphere

Boundary work is strongly culture-bound. There is overwhelming evidence that responses to new policy developments are strongly influenced by political cultures and regulatory styles[40-43]. In spite of divergences between national public epistemologies and the far greater variety of participants in international and transnational governance structures, there is also some evidence for the emergence of global or transnational cultures that influence national political cultures and policy styles.[44-46] The political-cultural sphere describes a particular governance space which coordinates the production, dissemination and acceptability of knowledges for political decisions. 'Knowledges' is used in the plural because normally political decisions have to align different types of knowledge from different actors: citizens, professionals, bureaucrats, experts. The cultural-political sphere (and the policy issue politics of a certain domain) acquires its special character precisely because it implicitly or explicitly manifests a particular civic or public epistemology, i.e. taken-for-granted expectations about the legitimacy and validity of these intertwined knowledges.[38, 41, 47]

In the next sections this heuristic framework will be used to discuss the most salient features of boundary arrangements for climate change policy and politics in the international arena and in selected Annex I and non-Annex I countries.

MAKING CLIMATE CHANGE INTERNATIONALLY GOVERNABLE

International boundary arrangements

A global climate change regime complex

Within the global climate change governance regime, or what some now refer to as a 'regime complex' due to its increasingly fragmented nature[48] and its growing differentiation as a maturing policy domain in many national and transnational settings, there exist 'numerous institutions that mix scientific and political elements in remarkably different ways'(Reference 25, p. 484). Key among the international 'hybrid' organisations for climate change are the rather well-researched Intergovernmental Panel on Climate Change (IPCC) which claims to coordinate the production of 'policy-relevant and yet policy-neutral' scientific work[49] and the arguably under-researched Subsidiary Body for Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on Climate Change (UNFCCCC), which has been referred to as a 'gatekeeper' linking the scientific information provided by the IPCC to the policy-oriented needs of the Conference of the Parties (COP).[24, 50] Related boundary organisations such as the Climate Bureau, the Subsidiary Body for Implementation (SBI) or the Intergovernmental Negotiation Committee (INC, 1990-1995), the temporary body tasked by developing countries[51] with steering the complicated international negotiations leading to the UNFCCCC, have hardly been researched.[52]

Collectively these international boundary organisations are embedded in and help constitute an emerging 'transnational multilevel governance culture'[5] around the issue of climate change. The boundary work carried out in international advisory bodies such as the IPCC and SBSTA to support the political bargaining in the COPs may be the sites of emergence of new forms of global civic epistemology.[47, 53, 54] Different from the relatively stable national public epistemologies, a fragile international knowledge order has to span a much wider diversity of scientific and political institutions from a huge number of countries and policy issue areas. This leads to confrontations between national epistemologies and boundary work arrangements.

Hybrid management at IPCC

The history of the foundation and early years of IPCC is such a clash between epistemologies and policy styles, in this case of US climate scientists, the US federal government, and the UN. Although the US in the 1980s and 1990s distrusted the UN as global governance regime, it strategically used elements of the UN expert-bureaucratic culture that stresses representation over expertise and includes direct but fuzzy boundaries between scientific assessments and negotiation forums.[55] By setting up a UN expert body, IPCC, and thereby transferring decision making to the global arena, US politicians reduced the domestic agenda setting power of US climate scientists who advocated climate action in bodies like the UN World Meteorological Organisation and UN Environment Programme. The intergovernmental character of IPCC, including articulate arrangements for dual participation and accountability, meant that the US government could keep some political grip on the international activities of US scientists and influence the boundary work practices in the IPCC. Even though IPCC was in practice a compromise between science and politics[51], it held on to a hegemonic US culture that stresses strict rules and a sharp, but transparent science-policy boundary[40] creating an image of IPCC as strictly scientific. This was more successful for Work Group I (doing the climate assessments) than Work Groups II and III (dealing with more mixed scientific and policy analytic issues of mitigation and adaptation, respectively). The rhetoric of maintaining a strict divide between science and politics was deemed crucial to upholding the legitimacy of both spheres of activity. According to Miller[15], this 'bring(s) the forms and processes of public policy-making into line with prevailing Western expectations about the nature of democratic governance and rational inquiry'(Reference 15, p. 60). However, in the back-office reality of practices in co-producing boundary objects, 'the very real changes taking place in global governing arrangements make clear the flexibility of categories like "science" and "politics" in international contexts'(Reference 25, p. 485).

The latter is especially clear in the boundary work performed in SBSTA. One of its roles is inter-organisational coordination and orchestration through the creation and maintenance of appropriate boundaries and jurisdictions between interacting organisations[24], delimiting the discussions appropriate to different institutions, for example, based on whether particular issues are considered political or value-based decisions (best dealt with by COP) and what are scientific issues (best dealt with by IPCC). Boundary work such as this is not limited to the SBSTA however,[30, 31, 51] for example Fogel[56] illustrates the complex mix of 'puzzling and powering' that occurs in both the SBSTA and the IPCC around issues such as defining the terms of reference of an IPCC special report (which occurred at the SBSTA), to struggles around the precise distinction between policy relevance and policy prescriptiveness (which occurred in the IPCC), to debates and struggles about the presentation and management of uncertainty (which occurred in the IPCC).

International policy issue politics' impacts on framing problem ownership, causality and accountability

A major impact which this international boundary work has had on the social status of climate change knowledge the world over is the way the policy issue of climate change was framed in the 1980s until the 1992 adoption of the UNFCCCC. Through this framing, the boundary arrangements were determined for the co-production of the science and politics of climate change until the 2009

events of 'climategate'. In addition to the politics of issue recognition and mobilizing political support, crucial cognitive steps were taken to structure and frame the climate change problem, which also determined the three elements that shape any public policy problem: problem ownership, causality, and accountability.[57, 58]

The first step was to settle the *causality* of the problem. In line with scientific consensus on a global climate crisis scenario and scientific practices of using Global Circulation Model simulations, climate change was politically defined as a *global* issue.[9, 15] This 'globalisation of the atmosphere'[15] came to side-line previously dominant discourses that had framed the increasing atmospheric carbon dioxide in terms of specific risks to local places. It also settled the *ownership* of the problem: only the UN as global governance regime could tackle a global warming problem. As Miller puts it: '[o]nly when the Earth's climate was re-imagined as a global system, bringing view of the atmosphere into line with assumptions about the jurisdiction of international institutions, did claims about climate change begin to engage with debates about international politics'(Reference 15, p. 51). Formally, problem ownership was settled with the adoption of UNFCCC in 1992. This meant that the issue was to be tackled through the institutional architecture and features typical for international multilateral agreements. UNFCCC and the Kyoto Protocol were constructed by analogies from past treaties on ozone depletion[7, 51] and nuclear arms. The designers thought the problem ought to be tackled through global emission controls, 'treating tonnes of carbon dioxide like stockpiles of nuclear weapons to be reduced by mutually agreed and verifiable targets and timetables.'[59] Problem ownership settled, *accountability* disputes immediately sprang up. The global scaling of the climate change problem results in a notable scale asymmetry experienced by local populations who are asked to meet locally concentrated short-term costs (around which there is little uncertainty), in order to reap globally dispersed future gains (around which there is considerable uncertainty).

This on-going issue of scale and time asymmetry inevitably involves both intellectual and political struggles on how to draw boundaries around problems[5] and in many cases the scientific and political struggles are difficult or impossible to disentangle, thereby endangering the productivity of both the powering and the puzzling aspects of boundary work. From a political 'powering' angle, policy issues that concentrate certain costs locally to achieve globally dispersed long-term and uncertain benefits require a fiercely entrepreneurial style of politics,[60] exemplified by both protagonists like Al Gore, and antagonists like the 'braking coalition.'[51] This framing impacted in two ways on national decision making climates. One is the political polarization between activists and 'wait-and-see' defenders, as in the US pluralist system. The other is dramaturgical incrementalism[61] manifest in EU and European countries' politics. It means grand-standing during COPs on (supra)national carbon dioxide stabilization or reduction targets, in full knowledge that public promises are unachievable in the normal channels of incremental policymaking back home. Both activists and dramaturgical incrementalists will be inclined to invite science to reduce knowledge uncertainty. Antagonists or 'deniers', in turn, will scrutinize the science for errors and uncertainties, becoming 'merchants of doubt.'[14]

From the other side of the boundary, for the cognitive 'puzzling' by scientists such issues of scale and time asymmetry also lead to disputes over uncertainty management. On the one hand, conscientious scientists communicate uncertainty in their results. On the other hand, they are aware of the strategic use of scientific uncertainties in politics.[51] Thus, scientists convinced about the truthfulness of their own research and especially of the need for politicians to take action, will be

tempted to deliver the certainty politicians desire. Looking at the stepwise increased certainty of IPCC statements about the probability of the anthropogenic part of global warming, it looks like this is what happened. The impression arises therefore that IPCC has not been able to fully resist the temptation of this 'stealth advocacy' using science to convince politics.[7]

In addition, and perhaps even more important, accountability struggles around the global framing of the climate problem can often be seen to drive a wedge between rich and poor countries. Thus many developing countries resisted the global, technical framing of the climate issue, based as it was on climate modelling in North America, Europe and Japan, arguing that issues of development, equity and poverty alleviation were fundamental, and should not be brushed aside in the new climate regime.[62] As Kandlikar and Sagar[63] have noted in their work on India, many people 'feel that climate change is an issue of lifestyles, and that the North needs to demonstrate commitment towards changing its unsustainable behaviour before it can expect others to do the same. From a Southern perspective, equity is an overarching, but constantly ignored theme in the climate debate' (Reference 64, p. 131). Various critical observers have similarly observed the fact that the interests and framings of the southern countries have not been appropriately or sufficiently well incorporated in the knowledge making practices of the IPCC.[16, 64, 65] For example Biermann[64] focuses on the IPCC's decision to divide emissions into just two categories (natural and anthropogenic) in its first report in 1995, rather than making a distinction (as advocated by some southern actors) between subsistence emissions (such as those resulting from rice farming and livestock) and more luxury emissions (such as those resulting from car transport). He suggests that far from being an inevitable apolitical decision, this correlated with the overwhelming participation of northern scientists. In light of the widespread awareness of the regional bias in participation at the IPCC, several mechanisms have been suggested in an effort to increase participation by developing country experts, notably by funding travel costs to meetings, and calls for increased funding for the development of climate models in southern institutions.

However, neither of these suggestions would alleviate the deeper discursive dominance of particular issue framings, and thus are unlikely to have any real impact on 'opening up' climate policy.[10, 42, 66] As Friman and Linnér[62] put it: '[s]chooling people in the workings of a closed discourse – that is a predefined way of framing an issue – is not the same as promoting an inclusive process' (Reference 63, p. 347). They argue that regional biases in the framing of climate change are tightly linked and partly result from particularly dominant disciplinary framings of the climate issue, particularly a 'non-inclusive biophysical discourse traditionally preferred by Northern policy makers' (*ibid* p. 339). The disciplinary biases in the knowledge making and validation processes of the IPCC/ UNFCCC regime have been commented on by various authors[67-70], and there is growing recognition of an 'epistemological hierarchy'[69] in the regime of climate governance, whereby certain types of knowledge, most notably the geophysical sciences, and economics[71], are promoted while others are marginalised. O'Neill et al argue that this bias matters because '[b]y marginalizing certain framings of climate change — framings which may help to address the "wickedness" of climate change — fruitful political and social responses may be excluded' (Reference 70, p. 998). In the section on non-Annex I countries we return to these issues.

Problem decomposition and priority for mitigation policymaking-by-proxy

All in all, when the scientific knowledge of the causes of atmospheric warming inspired a political problem definition as global warming[72] questions of problem ownership and accountability or responsibility were practically immediately given, and were to influence the chances of successful boundary work for decades to come. Yet another way in which particular framing choices can be seen to have had profound effects on climate policy is the way the overall problem was decomposed in 'doable' problem parts. This problem decomposition is reflected in the organisational structure of IPCC itself: keeping track of advances in 'sound science' in climate change knowledge (Working Group I), scientific and policy analytic knowledge about mitigation (carbon dioxide emission stabilization or reduction; Working Group II), and adaptation and vulnerabilities (Working Group III), and tasks to do with overall management, capacity building, etcetera (Joint Working Group, Bureau) and policy-analytic mediation in SBSTA and SBI between IPCC knowledge and COP/UNFCCC multilateral negotiations.

As has been highlighted by Pielke[7, 73], this problem decomposition by IPCC was in practice narrowed down even more, probably for feasibility reasons, by the negotiators of the UNFCCC. The first problem reduction was that not all greenhouse gases were equally addressed. Carbon dioxide was selected as the main target, thereby leaving approximately 40-50% percent of anthropogenic climate change unaddressed (Reference 7, pages 7 – 24). Second, the UNFCCC narrowed the definition of climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere' rather than any change in climate independent on the source. This narrow definition has meant that policy is skewed towards mitigation activities rather than adaptation, building on a linear conception of causality whereby it is mistakenly supposed that reduction in gases also means reduction in adverse effects. Furthermore, the framing of the ultimate goal of the UNFCCC as the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous atmospheric interference with the climate system' further influenced the dynamics of climate policy boundary work by limiting the basis for action of the UNFCCC.[74, 75]

As we show in the following descriptions of boundary arrangements and boundary work in selected countries, these global policy choices set in motion remarkable processes of cognitive and institutional isomorphism at country level. Given their different stances in the climate policy debates, for Annex I countries we selected the US and the EU; and a few member states playing a prominent role in EU climate policy – United Kingdom, Federal Republic of Germany and the Netherlands. For non-Annex I countries we opted for the largest two of the emerging economies, with the largest future carbon dioxide emission potential, and the most political influence, China and India.

Boundary work in the United States

The US as 'laggard'?

The United States has long been resistant to binding international emissions targets such as those laid out in the Kyoto protocol of the UNFCCC, or to federal-level emissions controls, preferring instead to focus on voluntary programs.[76, 77] Ironically, given their depiction as a 'laggard' in global climate policy, US federal funding for climate science is the largest in the world (approximately 2.6 billion dollars annually[78]). US scientists thus keep playing an important role in the IPCC but less so in national US climate change politics.[79]

The United states federal political system can be described as a pluralist polity characterised by public dispute rather than consensus[41, 79], and understanding the structural elements of this system is crucial to understanding both the US stance on climate change (internationally and at the federal/ sub-federal levels), and the impact (or lack thereof) of scientific knowledge in US policy-making . Of particular importance is the split between the executive branch of government (which articulates the US position in international negotiations) and the legislative branch, the Congress (whose support in the form of a two thirds majority vote in the senate is required in order to ratify international treaties). This system places a check on the extent to which the executive's international actions become domestic legislation, especially given that congress isn't necessarily controlled by the party of the president[80], and has led to remarkable continuity in the US international stance on climate change despite changes in political leadership.[81]

Domestic political concerns are also a crucial factor in determining the US position in international climate negotiations. These concerns (particularly in the shadow of recent global financial crises) have limited the extent to which the US could be seen to engage in actions that might be interpreted domestically as weakening its international economic status and strengthening its competitors.[82] A striking feature of the climate change debate in the US is its politicization (largely along Republican/Democrat lines). There exists a powerful, vocal (and largely Republican) climate sceptic lobby, whose views can be summed up in the words of the republican senator, Jim Inhofe, who famously argued that 'man-made global warming' was the 'greatest hoax ever perpetrated on the American people'.[83] While some observers have argued that the prevalence of industry-sponsored climate scepticism in the US is responsible for the US's lack of support for global climate governance mechanisms such as Kyoto, or for the lack of federal level climate policy in the US[14], others have argued that the presence of climate sceptics in the US isn't the cause of the problem, but a *symptom* of the way in which climate science has become inter-twined with a single policy framework.[12] Similarly, Pielke argues that regardless of the presence of sceptics, there has always been sufficient political support for action on climate change[84], a point which helps to explain the fact that despite the lack of central federal climate policy, a large number of climate policies *have* in fact been enacted sub-nationally, at the regional, state and municipal levels.[76, 85-88]

Federal-level boundary arrangements and organisations

Key among climate-relevant boundary organisations in the US is the US Global Change Research Program (USGCRP), mandated by Congress in the Global Change Research Act of 1990 (P.L. 101-606). The USGCRP coordinates and integrates approximately 2.6 billion dollars of climate related research across 13 executive branch departments and agencies (including the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA) among others), and is responsible for coordinating US participation in the assessments of the IPCC. The body whose task it is to integrate, evaluate, and interpret the findings of the USGCRP for policy makers, and develop an assessment of global change impacts and adaptation and mitigation strategies for the US, is the program of National Climate Assessments (NCA), coordinated by the National Climate Assessment and Development Advisory Committee (NCADAC).[89] NCADAC is made up of representatives from all participating federal departments as well as 40 non-federal members, and is required to submit reports to the president and Congress every four years.[90]

Some of the most important professional-academic bodies in the US are the US National Academies (incorporating the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council). These bodies are private, non profit institutions, who claim to 'provide expert advice on some of the most pressing challenges facing the nation and the world'.[91] Within this overarching structure, the Division on Earth & Life Studies of the National Academy of Sciences is primarily involved with climate research, and acts as an independent advisor to the US Global Change Research Program (USGCRP). With regard to climate modelling, the US system is diverse and 'fragmented', consisting of several competing academic research institutions funded by different federal agencies, each with its own approach.[92] This largely accords with Sheila Jasanoff's description of the pluralistic nature of knowledge making practices in the US civic epistemology.[41]

Aside from periodic scientific inputs into policy-making such as the NCA, on a day-to-day basis, the Office of Science and Technology Policy (OSTP) and the President's Council of Advisors on Science and Technology (PCAST) play important roles at the boundary between science and national policy-making. In line with the largely transparent nature of US politics, all federal advisory committees (including both the NCADAC and the PCAST) are subject to the Federal Advisory Committee Act (FACA) and are thus (largely) held in public, and reports from the meetings are made publicly available. As Sheila Jasanoff[41] comments, this builds on an important aspect of the civic epistemology of the US, whereby objectivity is detached from individuals and it is thus expected that conducting deliberations under the public gaze is 'the best way to wash out personal bias and subjectivity'(Reference 16, p. 269).

Sub-federal level boundary arrangements

In accordance with the relative importance of sub-national policy-making on climate change in the US[76, 88], there is evidence of an emphasis on locally relevant 'decision support tools' to aid managers and other local actors to make better use of (and steer future production of) scientific knowledge, and widespread interest in improving the science – end-user interface at the local and regional levels.[93-97] Examples of such attempts to bridge the 'gap' between scientists and 'end-users' at the local rather than national level, are the extension services provided by the National Institute of Food and Agriculture[97, 98], and the Regional Integrated Sciences and Assessments (RISA) of the National Oceanographic and Atmospheric Administration (NOAA)[95, 99], which is a series of 11 projects aimed at developing locally relevant use-inspired science and knowledge[96].

Boundary work in the European Union

The EU as 'leader' in international climate politics?

Unlike the US, the EU has always cast itself in the role of strong supporter, symbolic and diplomatic leader of an international climate policy regime. Like the US, the EU's role in global climate change policy was not devoid of self-interest[44]. Internally, the EU was looking to environmental issues as a new legitimation of its very existence; externally, climate change being perceived as the world's greatest sustainability challenge, claiming a leadership role provided the EU with an excellent opportunity to showcase its political identity to its own member states and their citizens (UK secretary of state Miliband in 2006, quoted in Reference 7, pages 106 – 7). Paradoxically, setting up itself as 'leader' over and against the US as 'laggard' helped boost the EU's 'actorness' in the global

political arena.[100] With low rates of population growth and very modest economic growth rates, climate policy comfortably aligned with European geopolitical interest as well because business as usual meant stable to decreasing GHG emissions (Reference 7, p. 106).

Boundary arrangements and organisations

The EU is a governance system specializing in regulatory policy and thus in need of advisory boards and epistemic communities offering scientific advice.[101] Developments at the international climate regime level, since COP1 in 1995, offered opportunities for environmental and climate policy entrepreneurs, organized in the Working Party on International Environmental Issues/Climate Change (WPIEI/CC). EU climate change policy is largely made by the European Commission's bureaucracy, especially the Directorates-General for Environment and Research, in Brussels, even though its major boundary organisation, the European Environmental Agency (EEA) is located in Copenhagen.

The EEA was established in 1993. Originally cast in the narrow role of independent information provider for policymakers and the general public, it was coordinating the European Environment and Observation Network (EIONET), with some 900 experts from 38 countries in national environment agencies and other bodies dealing with environmental information. As such it contributed to the early formulation of EU GHG stabilization targets and timetables. EEA is credited by some authors for strong conceptual contributions to climate change policy in the design of market-driven policy instruments, the precautionary principle (its study *Late Lessons from Early Warnings*, 2001) and methods and procedures for iterative risk assessment.[102] EEA experts' advocacy, since 1998, for market-based policy instruments[103] was resisted by DG Environment at first because EEA's mandate did not include policy design and evaluation. Since these functions were added in 1999, EEA developed into a full-fledged boundary organisation (Scott, 2000), and became 'over the years…a more loyal partner to the Commission … balancing the ability to have a credible voice … on the one hand and the need for stability and secure resource supply on the other.'(Reference 104, p. 881)[102, 104] As well as the EEA, several units of the Joint Research Centre (Institute of Prospective Technology Studies, Institute for Energy, Institute for Sustainability and Environment) perform boundary work functions for the Commission. Like the EEA, these JRC institutes perform their boundary work functions *de facto* as quasi-independent extensions of the EU bureaucracy.

Instrumentalized boundary work

The European Commission cherishes its boundary arrangements not only as resources for advice, but also as vehicles for political articulation of research questions and steering of knowledge production. Its European Research Area (ERA) initiative and the Framework multi-year research programmes are all strongly geared to the EU's knowledge demand. Using these instruments, the EU effectively creates boundary projects and ad-hoc arrangements that unite and coordinate research activities of major European knowledge institutes and universities, also on climate change issues. Swart et al. (2009) reports on the myriad boundary projects in European countries working on issues of climate adaptation. However, this actually ties the involved scientists and experts to instrumental contributions to existing policy lines; where they try to go for more conceptual and critical contributions, these are frequently nipped in the bud.[42, 103] Jordan et al.[105] conclude that since the EU's desire for international climate leadership has grown, 'climate policy instruments have if anything become *more* not less regulatory' (Reference 105, p. 544). At EU level, policy instrument

choice is strongly affected by the constraints of its highly complex decision making architecture. For example, a carbon tax proposal never made it because fiscal matters belong to the heartland of national sovereignty cherished by the member states. Market-type instruments, on the other hand, were acceptable because they leave national-political and business discretionary space factually untouched.[105]

Jordan et al also clearly show how policy instrument design is strongly influenced by national policy styles and cultures, and is not the technical, apolitical process that the label 'policy instrument' suggests. In a prophetic article, Wynne (1993) described the EU's emerging climate change policy as 'early warning' for the importance of political culture in policy design and implementation. He predicted for example how differences between economic sectors and countries or regions, especially between the North (Denmark, The Netherlands, Germany) and the South of Europe (Italy, Spain, Greece), would cause deep and lasting disagreements on binding carbon stabilization or reduction targets and timetables due to different carbon intensities. For scientific expertise this has meant that EU expert bodies like the European Environment Agency and national environmental expert bodies have been exposed to, on the one hand, trends of harmonization and expert consensus for the sake of creating a single European market, and on the other hand expert pluralisation along lines of national public epistemologies and, perhaps, disciplinary or paradigmatic viewpoints, for the sake of decision support to regional and national climate policy initiatives.[106]. On a more optimistic note, Wynne pictured the EU as 'social laboratory for global governance.'[107] Given its cultural pluralism and the North-South divide, the EU might act as pilot for opportunities and threats for richer policy design and fragmented, but bottom-up policy implementation. This prediction, of course, was refuted in practice. In the conclusion to this review, we will address these issues again in the global framework of the IPCC and UNFCCC. First we discuss the boundary arrangements in some major players in Europe.

Boundary work in the United Kingdom

UK national climate change policy

The climate change issue in the UK is framed in policy discourse as a 'global problem that requires a global solution.'[108] The UK signed the Kyoto protocol in 1998 (formally ratifying it in 2002). In 2000 the UK Climate Change Programme was published, which outlined how the UK planned to meet its Kyoto obligations through (among other things) a Climate Change Levy and a UK emissions trading scheme[109]. In 2008 the Climate Change Act[110] outlined a long-term legally binding framework committing the UK to an 80% cut in emissions from 1990 levels by 2050 (achieved through action in the UK and abroad), and putting in a carbon budgeting system that caps emissions over five-year periods. While emissions trading schemes are framed as a response to the climate change issue, the promotion of emissions trading by UK policy-makers can also be understood as strategies to favour the competitiveness of the UK economy.[111] In public discourse, although there is now near universal awareness of the concept of anthropogenic climate change in the UK[112] (and nowhere near the level of politicization or climate scepticism witnessed in the US), there is still evidence of some doubt about the reality and severity of climate change.[113] The general public tends to frame the issue as something distant and removed in space and time, rather than something that poses and immediate personal threat.[114]

Boundary arrangements and organisations

In their analysis of the policy networks associated with climate change in the UK, Turnpenny et al.[115] argue that the Prime Minister and the Treasury hold key influences in the government, 'more than in many Western countries', and argue that 'climate change action depends on the position of these actors' priorities'(Reference 115. p. 7). Officially however, the Department of Energy and Climate Change (DECC) is the lead department for policy on mitigation, while Defra (the Department for Food and Rural Affairs) and the Environment Agency are responsible for domestic adaptation policy and delivery respectively. The Climate Change Act of 2008 created the Committee on Climate Change (CCC) and the Adaptation Sub-Committee (ASC), independent expert bodies that advise the government on climate change, carbon budgets, and preparing for the impacts of climate change.[116] Both the CCC board and the ASC boards consist of a chair, together with 7 executive members appointed by the national authorities that are to have an 'appropriate balance' of skills and experience.[117] The composition of these expert bodies broadly accords with Jasanoff's characterisation of the civic epistemology of the UK[41], in which knowledge making institutions are built on the British conception of the public servant: 'persons of proven standing whose right to participate in knowledge-making for the state could not be seriously questioned' (Reference 16, p. 261). Another organisation that works explicitly at the 'boundary between scientific research, policy-making and adaptation practice, bringing together the organisations and people responsible for addressing the challenges climate change will bring'[118] is the UK Climate Impacts Programme (UKCIP), based at Oxford University. UKCIP has produced a number of influential climate scenarios[109, 119], that can best be understood as 'boundary objects', and the organisation itself has been highlighted as one of the key boundary organisations in the UK.[119, 120]

Dominance of natural-science based modelling and uncertainty reduction

Hulme and Dessai[119] refer to the 'epistemological hegemony of natural science-based climate models over other approaches to portraying the future' that is evident in climate scenario building in the UK, and a recent government review of scientific advice to government[121] underscores this observation, when it stresses that 'a key requirement underpinning many of the government's needs is to better understand, quantify and reduce the uncertainty associated with climate change projections… [and argues that] [h]igh performance computing and modelling capability is central to this' (Reference 121, p. 3). With regard to climate science, the Hadley Centre for climate prediction and research situated within the Met Office, is the main provider of evidence advice and other services to the government through the integrated Climate Programme, and the its model developments are also timed to coincide with deadlines for reports of the IPCC (*ibid*. p 5). The close relationship of the Hadley centre to government is seen as the most rational way in which 'modelling services' can be used to inform policy. Different from the preferences in the US system, a recent government review states, 'It would not make sense, or be economic, for departments to source core climate modelling services individually. There is positive advantage in a joint approach, and in having policies across government underpinned by consistent, high quality climate projections' (Reference 121, p. 2). While the Beddington line is the official one, there are critical voices emerging that question whether more detailed models are really what's lacking, and work coming out of explicitly interdisciplinary centres such as the Tyndall Centre highlights the irreducibly social nature of questions such as what constitutes a 'dangerous' level of climate change.[13, 74]

Boundary work in Germany

Climate change policy as 'avoiding catastrophe'

Germany has seen itself as an 'agenda setter' in international negotiations since the late 1980's[122], and has been influential in the commitments taken on by the EU under the Kyoto protocol.[123] Germany is the largest emitter of carbon dioxide in Europe.[124] It signed the Kyoto Protocol in 1998 and formally ratified it in 2002, and now has some of the most ambitious GHG reduction targets in the world (a reduction of 40% on 1990 levels by 2020).[125] However, Michelowa[126] argues that despite its self-positioning as a global climate policy leader, it will face significant difficulties living up to this image, and that, like in all other countries, the history of German climate policy has tended to illustrate that short-term economic interests frequently win key political battles. Unlike in the US case, there is little climate scepticism in Germany and there has been virtually no public debate about the strength of the scientific evidence on climate change, even after 'climategate'.[127] Similarly, 'public opinion and media appear to be lesser impediments to climate policy in Germany than in many other countries'(Reference 126, p. 157), and neither has decision making in Germany been hampered by remaining scientific uncertainty.[79] Certain philosophical underpinnings (such as the precautionary principle and the polluter pays principle) have been crucial to the development of German environmental policy ever since the first federal Environmental programme was adopted in 1971 and can be seen to have worked their way into international policy.[128] Another influential (some say the 'dominant'[127]) national framing of the climate change issue in Germany is that of an impending 'climate catastrophe', a phrase first coined in the late 1980s.

Boundary arrangements and organisations

One of the key events stabilizing the German climate science - policy boundary was the Enquete (Inquiry) Commission on Preventative Measures to Protect the Atmosphere, which was set up in 1987 during the heightened polarisation and competing scientific claims around the linked issues of nuclear safety and climate change, which emerged in the wake of the Chernobyl nuclear accident in 1986. Beck [127] argues that the Enquete Commission conformed to key features of the German civic epistemology: experts in the commission were selected by a political body rather than through scientific bodies as in the US, and the commission embodied a broad and inclusive form of institutional representation. As a microcosm of the society that would be affected by its policy advice, the Commission achieved increased trustworthiness whereby trust is typically a product of institutional affiliation, and objectivity is achieved through the broad incorporation of all the relevant viewpoints.[41]

Two significant boundary organisations mediate between science and politics in Germany : the German Advisory Council on the Environment (SRU), and the German Advisory Council of Global Change (WBGU). Institutions such as the WRGU play a role in delimiting uncertainty, as their website puts it: '[m]any political decisions have to be taken before the complex cause-effect relationships among global environment and development issues have been fully elucidated. Climate change is an example…. Despite the existing uncertainties, WBGU assesses hazards and identifies 'guard rails' that should not be crossed.'[129] Within government the German Ministry for the Environment, Nature Protection and Nuclear Safety (BMU) is responsible for climate policy overall, but several other government ministries share responsibility for different facets of climate policy. The Federal

Environment Agency (UBA) is Germany's central federal authority on environmental matters with a mandate to provide scientific support to the Federal Government and to implement environmental laws (e.g. emissions trading). Since 1990 an inter-ministerial Working Group on CO_2 Reduction (IMA) has served to coordinate climate policy across these government ministries.

Boundary work for climate change in the Netherlands

Re-politicizing climate change policy?

Since the 1970s Dutch environmental policymaking has evolved from a mono-sectoral to a multi-sectoral policy subsystem, evidenced in a series of National Environmental Policy Plans that coordinate overlapping policy areas. Climate change slowly gained the status of privileged emblem in environmental policy. In the 1980s, a no-regrets climate policy was launched. Since 1996, Dutch climate policy has been guided by the precautionary principle. However, since 2006 public and policy debate has been re-politicizing, sacrificing this principle when expedient. For example, inspired by an international re-prioritization of climate adaptation, the ad-hoc Delta Committee formulated new strategies for water management. The Committee chairman instigated a fierce controversy when he defended the choice of a worst-case scenario of sea level rise between 0.65 and 1.3 m as 'science-based', which undermined the impact of its advice.[130] Economic efficiency and implementation feasibility favoured choosing the Royal Dutch Meteorological Institute's (KNMI) and IPCC's 'more plausible' sea level rise projections of 0.35-0.85 m, thus trumping the Committee's political choice for a precautionary worst-case scenario. The rise of a new and highly successful populist political party, the Party for Freedom (PVV), has given climate sceptics and deniers a voice in parliament. One political implication is the appointment of a climate-sceptic science journalist as special government advisor , tasked with detection and correction of errors in the upcoming IPCC's Fifth Assessment Report. In the past this would have been indisputably a task for the established knowledge institutes, MNP/PBL and KNMI, discussed below.

Boundary arrangements and organisations

The Dutch have a strongly developed and institutionalised public architecture for the governance of science-based expertise and policy advice.[131] For environmental issues its legally established knowledge-and-advice institute is the Environmental Assessment Agency (formerly MNP now PBL). The MNP/PBL has a broad mandate, ranging all scale levels and covering all aspects of policy analysis from forecasting and scenario-building to policy design, monitoring and evaluation. It has the capacity to contribute to modelling and scenario studies for every aspect of the climate change issue on a global scale.[132] In addition to MNP, boundary work functions are performed by expert organisations like Deltares (for water management), Wageningen University and Research Centre (for land-use and agricultural aspects), and the Royal Dutch Meteorological Institute (KNMI).

Dutch climate policy is coordinated with EU policy in an interdepartmental Task Force Kyoto Protocol, consisting of departmental representatives, the Dutch negotiators at European and IPCC/UNFCCC levels, and representatives of the MNP/PBL. MNP/PBL has been tasked to deliver instrumental and conceptual knowledge contributions to climate change policy by the Dutch state, the EU, and, from the very start, IPCC. It has used its own and IPCC-generated knowledge to depoliticize public debate by acting as guardian or 'linesman'[133] for public and policy debates. After 1996, Dutch climate policy attempted to push on from the precautionary to the *prevention* principle.

Starting with global and EU goals, such as limiting global warming to 2°C to avoid 'dangerous human interference', policy analysts calculated what the reduction targets for The Netherlands would be. This heuristic presupposes more certainty about acceptable risk than the precautionary principle. Hence, IPCC was imbued with more and more certainty-by-authority; and was pushed in the role of 'certification machine'.[134] In the early 2000s, MNP confronted an internal dispute over the credibility of modelling and simulation versus observational methods of knowledge production. The internal quarrel between experts spilled over to parliamentary debates on trust in the institute's quantitative policy support. MNP survived this crisis by adopting and implementing explicit guidelines for dealing with scientific uncertainties.[30, 33]

Boundary projects for adaptation

Finally, the re-orientation toward adaptation policy, spurred by the Dutch' eternal struggle against the sea, has initiated lots of boundary work projects, for instance the multi-year consortium for 'Knowledge for Climate' which focuses on the implications of climate adaptation for a number of Dutch 'hotspots'. Some see this as a chance to restore public trust in climate science through nationalizing climate expertise.[135, 136] The MNP/PBL recently positioned itself as a discourse coalition builder between green governmentality and ecological modernization through its report 'The energized society, towards a governance philosophy for a clean economy'.[132] All in all, after two decades of using climate science as 'certification machine' in closing down public debate, it looks like the climate debate in The Netherlands is opening up in a politically and policy relevant way.

Boundary organisations in non-Annex I countries India and China

Nationalistic framing of the climate change issue

The overall response to international climate change science-policy developments in the two prominent non-Annexe I countries India and China is similar in many respects to Brazil's position.[16] Climate change was initially only on the agenda because of UNFCCC negotiations and therefore was, and remains, mainly a foreign affairs issue. The perceived need to respond to such external policy initiatives has often driven analysts' efforts to develop a national perspective and to build linkages with domestic policy-makers.[63, 137]

In China and India, energy is seen as the key to economic development and this is a main cause for unwillingness to take on emission reduction commitments. Hence, the international framing of climate change policy as mitigation hindered explicit national climate change policy-making, even though policies were developed that contributed to the same goal. For example, Chinese policy-making towards emission reductions was not linked rhetorically to climate protection but to domestic problems of air pollution and energy shortages[138, 139] and in India a number of initiatives was taken in relation to the energy and forestry sector which are to a large extent compatible with the requirements of international climate change policy but are not framed as such.[17] Vulnerability to climate change is an emerging issue and this could contribute to elevating the climate change issue on domestic agendas in the future. So far, international policy such as the Clean Development Mechanism (CDM) is mainly used to help solve domestic problems.[140] However, recently the Indian government has tried to reframe prevailing political discourses on climate change by introducing new frames and storylines that emphasize climate change as a national concern rather than as an international matter[141] and China has adopted a more proactive attitude toward climate-change

mitigation because after three decades of rapid economic growth the Chinese government wants to facilitate an environmental transition.[142]

Both countries argued that historic responsibility for climate change resides with the developed world and international emissions caps are viewed as 'deepening the north–south divide' by capping emissions just as its development is taking off. [143] In India there is a strong perception that the international negotiation processes are merely the latest disguise for continued economic and political domination of developing countries by the industrialized North[144] and that getting into substantive discussions may only weaken the position of the country.[17]

Boundary arrangements and organisations in China

Foreign funding for climate change policy analyses is dominant in both India and China. Multilateral and bilateral agencies attempt to impose their own (dominant) views of these countries' role in 'global' policy for climate change, so policy analysis is biased towards mitigation rather than the assessment of vulnerability and adaptation strategies which is more relevant for national policy-making.[63] Policy and research agendas on climate change in China were initiated by US funding and cooperation in a joined research program about the impacts of carbon dioxide on climate change; the scientists involved were the first to put the topic of climate change on the Chinese agenda.[138] Foreign funding also helps keep issues on the donor agencies' agenda alive in Indian science and policy circles.[145]

However, due to their very different political systems and public epistemologies India and China's boundary arrangements are very different. In the authoritative Chinese tradition, protective of the idea of the wise state leadership, there is no scope for public relativism, which explains why politics and policy issues can be very sensitive areas and why positions regarding all policy issues, including scientific results on climate change, have to be coordinated with central political institutions.[146] In China climate change is highly politicized because it goes far beyond the emissions reduction to cover a wide range of issues such as global economic and technological competition, national security and development, distribution of wealth, and world leadership.[142] Therefore, climate change policy research is politically sensitive and centred in Beijing, close to policymakers. At the same time as being submitted to political control, science and technology are cornerstones of the positivistic and materialistic world view that permeates Chinese society and its communist ideological foundation. Therefore scientific results and findings are taken very seriously. Some observers believe that it is the political will of the Chinese leadership to boost academic knowledge to raise awareness of climate issues, in particular to pave the way for climate measures.[139] The exact intersection between the Chinese epistemic communities and political decision makers is hard to follow from the outside, but China experts agree that the flow of information and arguments between the two communities can be considered high and influential on policy-making.[140] There appear to be hardly any boundaries between the two worlds when it comes to policy statements: they speak with one voice, with scientists unquestionably loyal to political leadership.

China's climate policy is largely formed by one commission and a few ministries. The main coordination body for climate policy is the National Coordination Committee on Climate Change (NCCCC). Its members are the National Reform and Development Commission (NDRC), the Ministry of Foreign Affairs (MFA), and 13 other ministries and government agencies. The leading bodies of the NCCCC have research units or advisory departments that specialise in climate policy issues but

they also increasingly work with academic institutions. Research institutions and academic organisations are closely related to governmental agencies and they often succeed in influencing the work of public administration (OECD 2005). The two key institutions that conduct climate policy research and advise the government on climate issues are the Energy Research Institute (ERI), which is affiliated with NDRC, and the Research Centre for Sustainable Development at the Chinese Academy of Social Sciences (CASS), which operates under the State Council.

Boundary arrangements and organisations in India

India has a relatively stable democratic political system, a relatively well informed governing class, a free press, a well-established scientific community and active nongovernmental organisations that should, in theory, be well-placed to support, promote and demand quality climate change-related policies. However, freedom of information has been an issue. Until 2005 access to governmental documents and technical reports were available, if at all, only through leaks or other informal channels[147]. In 2005, the Right to Information Act was introduced and climate activists and researchers have used it to get access to government documents.[148] Mistrust in scientific institutions and a lack of regional knowledge may adversely affect both mitigation and adaptation efforts.[141]

Also modelled on the British system, links between scientists and policy makers often operate in an informal manner. Generally, India's 'policy for science' has been dictated by close alliances between powerful leaders and their scientific advisors. These experts might be called upon to provide rapid advice on a particular issue, as and when needed, produce position papers upon request, and to participate in more structured activities to inform and guide policy-makers prior to UNFCCC or IPCC meetings. Many of these advisors are over-subscribed and play multiple roles: as scientists and analysts, as advisors to the Indian government, and as members of the IPCC or other international bodies. Although this places limits on the time that the top cadre of experts can devote to active research, it also allows them to gain a comprehensive view of issues surrounding climate change, and to develop a well-informed stance. There is substantial turnover in the personnel handling any particular issue in the government. Consequently, the Ministry of Environment and Forests lacks a systematic approach for dealing with climate change, and there are almost no mechanisms for building in 'institutional memory' on the issue. This has led to frustration among many in the research community about the lack of interest in climate change issues at the policy level and the minimal role that expertise seems to play in India's stance at the negotiations.[63] Kandlikar & Sagar's 1999 assessment was confirmed by the 2010 Climate Revolution Initiative report.[148]

Policy analyses of the social, economic, and technological aspects of climate change are primarily conducted at a few large NGOs, research institutes, and some academic institutions. The Tata Energy Research Institute (TERI), a think tank in Delhi, and the Center for Science and Environment (CSE), a Delhi-based NGO, are the two most prominent players. They have been involved since the inception of climate policy and offer a traditional understanding of policy engagement through proximity to government actors and involvement in policy networks.[149] The timing and targets of their efforts are often chosen strategically to make an impact upon the Indian policy stance. TERI is a mainstream organisation whose advice is important to the government. CSE emerged as one of the most articulate and influential environmental voices in India. The close networking of Indian bureaucratic and intellectual elites ensures that CSE's views will not in general be dismissed as those of an isolated fringe group. On the contrary, CSE appears to enjoy almost a symbiotic relationship with the

Ministry of Environment and Forests (MoEF). As NGO representatives they are free to adopt positions that would be too risky for the Ministry, but their widely read reports serve as early pointers to future government policy - especially on global environmental issues that are not yet touched by the complex dynamics of domestic regional politics.[147] It was CSE who in their 'citizens' report'[150] challenged the assumptions behind the calculations in a 1990 report of the World Resources Institute (WRI) which stated that developing countries ranked high among greenhouse gas emitters because of deforestation and other human activities resulting in carbon releases, thus showing the importance of scrutinising 'Western' science.

To aid information flows and enhance the credibility of national climate policies the Indian government has recently instituted the Indian Network on Climate Change with involvement of various scientific bodies around the country, the Mission for Strategic Knowledge as part of the NAPCC, and the Low Carbon Expert Group comprised of representatives from government, industry and civil society.[141] It is too early to assess what impact these organisations have.

The overall picture of science-policy interaction is (a) general lack of scientific capacity to provide knowledge needed for policy-making, and (b) bias towards producing science for international negotiations. Globally, the majority of the climate analysts are from industrialized countries and their work has generally focused on issues directly relevant to these countries. Members of the Indian research community are acutely aware of this ideological divide, and more specifically, of the political nature of the international assessment process. They recognize not just the South-North divide on climate change emissions and responsibility, but also in the inequities in the assessment capability, as well as the broader international context (such as economic globalization) in which the climate change issue sits. Their concerns vis-a-vis climate research and assessment include inequities in participation and decision-making about agendas, in funding, in research infrastructure, and in the representation of, and barriers to the acceptance of, ideas.[63]

CONCLUSION: LOST IN THE PROBLEM

The social status of climate change knowledge

The question of how international and national boundary organisations have impacted on the social status of climate change knowledge can be approached from two angles: the social status amongst the general public and the social status in policy making. Although the former impacts the latter through politicians' sensitivity to public opinion, in this review we focussed on the latter. A brief review of literature on the social status of climate change knowledge suggests that while public opinion on climate change does vary cross-nationally (and not always in predictable ways)[151], in most Western countries the issue is considered psychologically distant in space and time, with low urgency and personal relevance[152]. Furthermore, despite differences in policy discourses, public opinion on climate change is largely comparable between for example EU countries and the US.[153] It is seen as a collective action problem awaiting more certainty about the behaviour of others and the effectiveness of policy instruments. Adaptation problems may bring the problem nearer to most people.[134, 154]

With respect to the social status of climate change knowledge in policy discourses, it should be clear from this review that policy 'use' of scientific knowledge is highly dependent on political and societal contexts. Seemingly good boundary work and effective boundary arrangements do not necessarily trigger meaningful political debate or political decisions that tally with scientific results. Bearing this in mind, we can still evaluate international and national boundary work and boundary arrangements using other criteria than direct policy impact.

Evaluating international boundary work

Overpoliticization

Boundary work can be evaluated in terms of politicization of science and scientification of politics.[155] Arguably both (over)politicization of science and (over)scientification of politics could be considered a failure of boundary work: it indicates that the science-policy coordination went too far, ignoring the demarcation that is also required for good boundary work.[28] At the international level, both Demeritt[4] and Sarewitz[12] argue that politics seeped into climate science because of the global framing and the association of climate science with just one policy option, i.e. the Kyoto Protocol. The scientification of politics or the 'rendering technical'[156] of climate change also appears to be widespread. For example Friman and Linnér[62] show how equity issues were transformed and obscured by technological debates and discussion at the IPCC, when 'the historical responsibility issue became stranded on problems of how to correctly represent physical nature in climate models' (Reference 62, p.339). Good boundary work would draw more on politics to deal with value issues and more on science to deal with knowledge issues, while organising and managing the interweaving of both.

Good boundary work would also help to structure the policy problem towards solvable (partial) problems. However, as argued in detail by Hulme[9], after three decades the climate change issue has remained a thoroughly unstructured or wicked policy problem. On the normative side, ethical divisiveness is persistent. For many politicians and policymakers the climate change issue is high politics, where the relation between competing values like economic growth and sustainability remains contested, and maybe a complete overhaul of the capitalist economic world order with our political, ethical and religious lifestyles is at stake. Relatedly, the role of the state versus economic and civil society organisations in tackling the issue is a continued source for ideological struggles complicated by the problem of how to shape the national, trans- and international responsibility and accountability aspects of the problem. Issues of international distributional justice/equity were insufficiently tackled, and the concentrated short-term costs/dispersed and long-term benefits problem remains unsolved. On the knowledge side, instrumental knowledge for successfully coping with possible adverse effects of climate change remains underdeveloped and uncertain. Pielke[7] observes that '(T)he bottom line… is that no one really knows how to accelerate the decarbonization of large economies' (Reference 7, p. 111). Finally, due to deficient problem decomposition important aspects of the problem like adaptation, decarbonisation through energy innovation and ethical aspects of geo-engineering have not yet been seriously considered.[7]

Wrong-problem problem

The implication of this analysis is that there is a gross mismatch between the 'wicked' nature of the problem and the international (and a good deal of the national) boundary work architecture. As

argued above, IPCC aimed for technical-specialist advice that would be instrumental, serviceable and solution-oriented – i.e. 'sound science'-based advice for solving adverse impacts of climate change as a structured policy problem. This suggested a linear, instrumental approach to scientific policy advice for regulating 'one' global warming problem, to be tackled in a 'sound science' informed, harmonized, and standardized way for 192 countries of the UN. Since its early beginnings in the 1980s, the international community has doggedly clung to this approach. Resisting its hybrid character to a considerable extent, according to Shaw IPCC never developed its potential for co-production between science and politics to the full.[157] Siebenhuner[158] compared policy processes of several international multilateral agreements on the social and policy-oriented learning dimension. In the case of IPPC/UNFCCC, he observed only first-order, instrumental learning. No second-order reflexive learning took place, i.e. changes in the prevalent knowledge system, reinterpretation of purposes, choice of policy instruments or governance strategies. Haas[159] similarly judges that, although the early IPCC may have been successful in international agenda setting and in upholding credibility in climate knowledge (until 'climategate'), its legitimacy (for the US and developing countries) and salience (for all countries) were actually rather low: 'the IPCC is designed to keep science on a tight leash by controlling the selection and autonomy of individual scientists engaged in the assessment process. Consequently, the degree of usable knowledge generated by the IPCC has been limited' (Reference 158, p. 583).

Incomplete problem definition

Another and possibly more important reason why climate scientists have been unable to trigger more meaningful political debate is the hidden difference between the broader problem definition of climate change by IPCC and the narrow one by UNFCCC limiting the scope of policy action to carbon dioxide, mitigation and dangerous interference. Instead of 'reasoned problem choice by accountable politicians'[160], this problem definition, developed in the chaotic politics of international bargaining in INC during the preparatory stages of the UNFCCC, created a *wrong-problem* situation. This is a case 'where political or administrative institutions with the authority and power to define and delineate a problem space either (a) consider a problem structured where it should instead have more plausibly been defined as moderately structured, or (b) where it is defined as moderately structured when it is actually completely unstructured…'(Reference 39, p. 86). In the long run this politically schizophrenic situation in no small measure contributed to IPCC's 'deconfiture' in the events of 'climategate' and subsequent exposure of mistakes in the Fourth Assessment Report. Hybrid management of global boundary work in the political snake pit of global warming politics required careful rhetorical oscillation between sacred/profane and front/back-office accounts of IPCC's international workings. Under ever more scientific and political scrutiny due to its ever stronger statements on the certainty of the anthropogenic part of climate change in its successive assessment reports, and yet unable to be transparent to politics and science at the same time because the taboos in their sacred narratives, IPCC's boundary work became gradually more and more entangled in what Brunsson[11] aptly called 'management by hypocrisy'. When the deliberate or inadvertent leaking of email exchanges between leading climate scientists indicated manipulation of the peer review process[7], IPCC's reputation for credibility went into a downward spiral in western countries, while legitimacy problems within developing countries were only confirmed. Direct repair work on credibility by the IAC leading to minor adjustments in IPCC protocols proved to be 'too little, too late'. In COP15 at Copenhagen the entire UNFCCC/Kyoto process came to a standstill.

To summarize, from the fragmented and disjointed processes of 'puzzling' and 'powering' in the framing years of the global climate change issue a wrong-problem problem situation was born. IPPC and other international boundary organisations were set up for addressing a (moderately) structured problem, instead of geared to an as yet full-blown wicked problem. Instead of being designed as 'certification machine' and 'scientific trigger' to depoliticize a multilateral international agreement and its supposedly smooth implementation, IPCC should have been designed as a conceptual, critical and problem-oriented scientific and stakeholder forum for discussing and preparing strategic advice through opening up political debates and demonstrating the 'serviceability' of more than one type of policy discourse. The little studies of SBSTA seemed more successful at this at the time, albeit much slower to produce agreement.[24]

Learning from national boundary arrangements?

Boundary arrangements at national levels showed cognitive and institutional isomorphic response patterns to international global warming politics and boundary work. In all our country studies the highly instrumental nature of boundary arrangements, organisations and projects stands out, serving the political interests of states (in EU and EU countries, and in India and China) or political interest coalitions within a country (US). This affirms that having 'our experts' is crucial in national and international boundary work. Boundary work theory implies that expertise is a social relationship between a provider and user of expertise. Therefore, 'nationalized' expertise provides higher trust (closer sources are more credible) and political control (closer link between science and national politics).[42] The US efforts to 'inter-governmentalize' the IPCC were inspired by the same logic.

In developing countries like China and India boundary work is in its infancy. In China, this is due to near-absence of a discernable boundary between science and politics. In accord with Communist ideology and political architecture, boundary work is thoroughly bureaucratized inside government where scientists are unquestionably loyal to political leaders on penalty of (at best) exclusion and marginalization. In India, boundary work for climate issues occurs mainly in informal, personal contacts between politicians, policymakers and scientists, sometimes working in state-supported think tanks, although boundary arrangements have recently been set up. However, in both countries, after initial resistance to the climate change issue as another vehicle for continuing western dominance in a globalizing economic world order, the issue is somewhat gaining in legitimacy and salience mainly through embedding in other related national policy issues such as energy. Explicit climate change science and policy remain aimed at participating in UNFCCC negotiations and IPCC assessment work.

In the EU and EU countries we observed centrally harmonized and coordinated, instrumentalized boundary work arrangements and projects. Although each country has its own policy style and public epistemology and hence adopted climate change norms and standards at different speeds[161], this does not hamper coordinated climate change policy processes at EU level. In that sense, Wynne's idea of the EU as a pilot for multicultural climate governance has come true[107], also in the then unanticipated sense that the structural political affinities between the EU and UNFCCC/Kyoto as international governance structures elicited the strong support of the EU. Very different from the US, the EU uses its quasi-independent and decentrally located boundary organisations as vehicles for demand articulation and steering of climate change knowledge. In addition to the institutional self-interest in supporting a unitary and top-down international climate regime, this makes for very

instrumental boundary work that would not challenge problem definitions and belief systems at global or national levels.

In the US, a pluralist political structure and culture leads to a polarized and politicized set of boundary arrangements, external to government, and with a sharp boundary between science and politics, although most climate science is government-sponsored. Fragmented, disjointed and experimental policymaking processes that are normal for politics in a federal system have created a contradiction between federal government as sceptical, and many state and regional and municipal governments as supportive of climate change policy. Local extreme weather conditions like Katrina or the annual hurricane season may have contributed to (sub-)state level willingness to initiate and implement adaptation projects. Therefore, interestingly, the situation in the US has created contradictory tendencies in climate change politics that have frequently led to a 'dialogue of the deaf', but have at least the potential of opening up public and policy debate.

While some authors have focused on examining potential ways in which key boundary organisations such as the IPCC could improve their effectiveness, like the 'earth system governance' project[162], others see increasing fragmentation of the climate regime, the uncertain and variable status of climate change knowledge, and the apparent failure of policy to achieve meaningful emissions reductions, as evidence of a fundamental flaw in current global framings of the climate change issue.[163, 164] They suggest that the inability of COP15 to reach any meaningful agreement on emissions reductions signals the end of the era of global top-down policy instruments such as Kyoto, and perhaps the start of a new approach to the global issue of climate change including more diverse measures[59] or a return to 'mini-lateralism'.[165] In a related vein, others draw hopeful attention to the growing divide between what is actually happening in the world in terms of diverse policy-making initiatives, and the global climate policy talks.[166]

Ways forward

What, then, can, and perhaps should be done at this point? For climate change as unstructured problem, boundary work should aim to provide pluralized strategic advice, conceptual clarification, and critical deconstruction of issues of uncertainty and normativity. It should be more problem- than solution-oriented in debates and influence different agendas in different parts of the world. The international boundary arrangements should move from being geared to a central-rational rule approach to a much more disjointed, geographically differential-speed incrementalist innovation policy process. "Innovation" in the double sense of "governance of innovation" (e.g. of energy decarbonisation) but also "innovation of governance" (away from outdated, inflexible UN multilateral agreement strategies)[167].

Opening up political and policy debate obviously requires the facilitation and stimulation of more than one scientific theory on climate change, so more space should be given to climate scientists who follow research lines normally considered marginal instead of safely inside the consensus zone. Politicians should no longer cast science in the role of certification machine, but will have to develop their own local or national responses to climate change in their own terms. If possible, politicians should escape from fear of climate change dystopias[168] and develop mobilizing visions of adaptation to climate change. Hajer's (2011)[131] 'energized society' and 'greening of the economy', Pielke's proposals for all-out innovation for energy decarbonisation[7], or discourses on 'civic environmentalism'[169] could provide inspiration. Scientists should resist becoming 'stealth advocates'

and assume roles of honest brokers[7, 170], positioning themselves as (transnational) citizens with a special responsibility for democratic political debate. For IPCC the radical implication may be its dismantling, except for the scientific assessment tasks of Working Group I. Instead, it should be reconstituted as a global "UN Centre for Climate Change" for study of potential approaches and instruments for climate policy-making, engaging in reasoned debate on problem structuring and alternative ways of problem decomposition, and establishing and developing 'situated' branches, supporting national, regional, local and manifold transnational policy initiatives through a portfolio of approaches and strategies of democratic experimentalism.

Apart from this there is good reason for more empirical research using the boundary work lens for lesson learning. The intensive boundary work at SBSTA, SBI and in 1990-1995 INC, has hardly been studied, yet it is imperative for good climate policy to gain more knowledge of policy-analytic boundary work for instrument design[171] in multi-stakeholder and high-negotiation settings. Equally, little is known about boundary work *per se* even in countries like the FRG or the UK, let alone in developing countries. Given the international and transnational character of collective action on the climate change issue, a return to only local incremental governance approaches is not desirable. It is therefore imperative to closely study and learn from global-local boundary work dynamics[45] and study if and how incremental approaches trigger policymaking responses in other countries or levels of governance.[172]

Lesson drawing and best practice research, however, have their limits. This is partly because they do not travel easily from one context of application to another: boundary work experience with ozone depletion, nuclear radiation and acid rain turned out to be not very usable for climate change. More importantly, our inability to know enough forces us at some point to stop the cognitive process and shift to action. Hence, any learning in a political task field should not be limited to scientific research and lessons based on analysis; it necessarily takes the shape of pragmatic trial-and-error learning by variation-and-selection. We hope that this analysis of boundary organisation and boundary work for climate change knowledge and politics becomes part of a larger learning process for renewed efforts to create and maintain a productive and creative tension between science-as-puzzling and politics-as-powering in the struggle over policy.

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Figure Captions

Figure 1. Multi-level conceptual framework for understanding science-policy interactions